Microgrid with DERs and its Operation Security

Team members: Saikat Das, dass10@vcu.edu, Zhifang Wang, zfwang@vcu.edu

VCU Electrical and Computer Engineering
College of Engineering

INTERNATIONAL Microgrid SYMPOSIUMS

Overview:
- Developed a multi-layered microgrid simulation model.
- Integrated an optimization-based EMS into the model.
- Investigated two critical aspects: data loss and FDI attacks.
- Explored the impact of these aspects on the optimization and security of microgrid operations.

Energy Management System:
EMS ensures reliable functionality, maximizing renewable energy penetration, and optimizing cost and economic efficiency.

Microgrid Operation Strategy
- Simulating probabilistic data loss in battery command to asses the economic impact in the microgrid system with increasing data loss.
- Simulating FDIA in EMS
  - Combining optimization based EMS with adaptive control schemes.
  - Optimization-based EMS in normal condition and adaptive control modes during islanded operation upon FDIA detection.
  - Prioritizing economic efficiency under normal conditions, while dynamically adjusting objectives in critical conditions

EMS Objective Function

$$\min\left(\sum_{t=0}^{N}\left(C_{grid}(t)\times P_{gria}(t)\right)\times\Delta t+\sum_{t=0}^{N}\left(P_{gen}(t)\right)\times C_{gen}\times\Delta t+\sum_{t=0}^{N}\left(P_{batt}(t)\right)\times C_{batt}\times\Delta t\right)$$

$$P_{pv}(t)+P_{grid}(t)+P_{batt}(t)+P_{gen}(t)=P_{load}(t)$$

Constraints

$$E_{batt}(t)=E_{batt}(t-1)+P_{batt}(t)\times\Delta t$$

$$X_{min}\le X\le X_{max}$$

FDIA Model

Continuous Intensity FDIA Model

$$if\ t_{start}\le t\le t_{end}$$
$$I(t)=random(I_{max},I_{min})$$
$$D_{att}(t)=\ D_{act}(t)+\frac{I(t)}{100}\times D_{act}(t)$$

Probabilistic Intermittent FDIA Model

$$if\ t_{start}\le t\le t_{end}$$
$$I(t)=random(I_{max},I_{min})$$
$$D_{att}(t)=\begin{cases}D_{act}(t)+\dfrac{I(t)}{100}\times D_{act}(t), if\ random(0,1)<\varepsilon_{attack}\\ D_{act}(t), otherwise\end{cases}$$

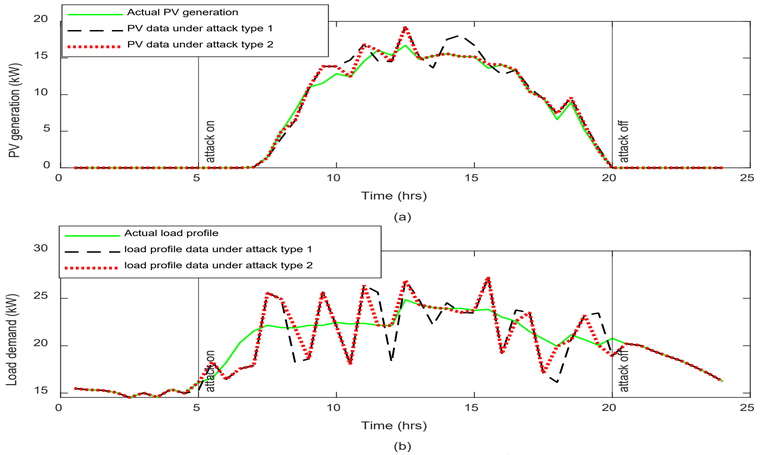


Fig 1.(a) PV generation data under 20% FDIA, (b) Load profile data under 20% FDIA

Optimization-based EMS

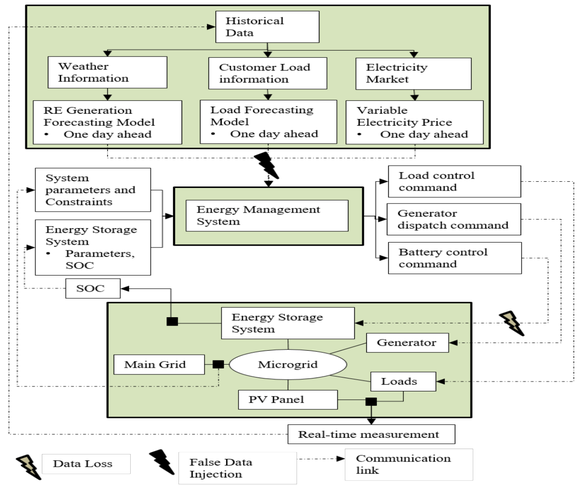


Fig 2. Working flow for the optimization-based EMS

Microgrid Operation: Adaptive Control

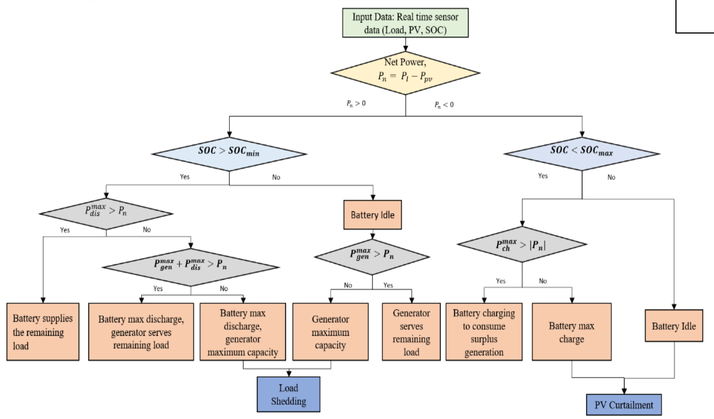


Fig 3. Working diagram for adaptive control schemes for microgrid operation

Result and Analysis: FDIA

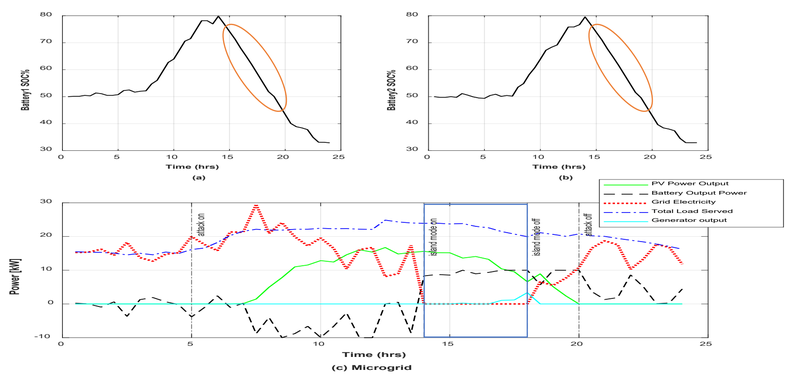
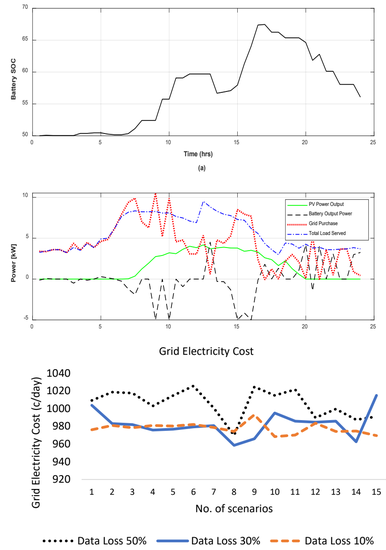
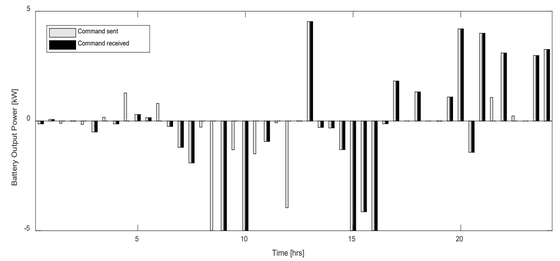


Fig 4: (a) SOC of BESS1, (b) SOC of BESS2, (c) Power profiles of PV generation, battery output, grid electricity, generator output and total load over time using hybrid EMS method under FDIA type 1

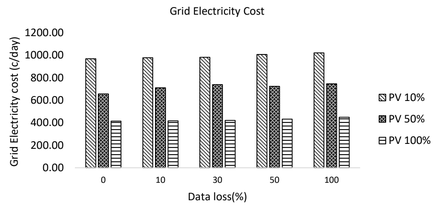
Result and Analysis of Data Loss Attack



Comparison of grid electricity cost for the microgrid with 10% PV penetration with varied amounts of data loss



A specific case of 50% PV penetration scenario with 30% data loss in the microgrid (a) State of charge of the BESS, (b) Optimized power profiles of PV generation, battery output, grid electricity, and total load over time, (c) Battery charging/discharging command



Comparison of average grid electricity cost for varying PV penetration and data loss rate in microgrid

Result and Analysis of False Injected Data Attack

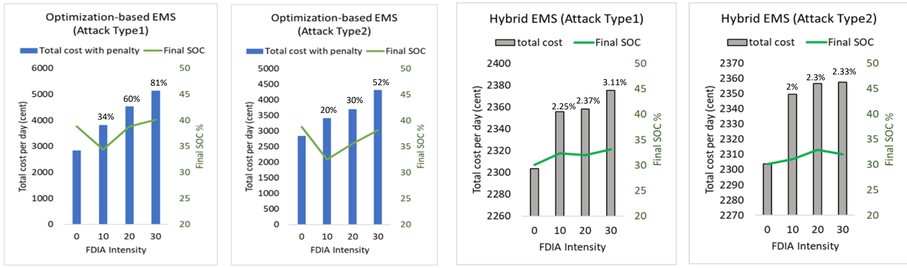


Fig 5. Total electricity cost and final SOC with increasing intensity of FDIA type 1 & type 2 in 24-hour microgrid operation for optimization-based EMS

Fig 6. Total electricity cost and final SOC with increasing intensity of FDIA type 1 & type 2 in 24-hour microgrid operation for hybrid EMS

Table. Summary of Microgrid Operation Under Various FDIA Scenarios

Microgrid Operation Method	FDIA time	FDIA intensity (%)	FDIA type	Islanded mode operation time	Total cost for electricity per day (c/day)	SOC of BESS (%) at the end of the day	Load shedding (%)	Total cost considering penalty for load shedding (c/day)
Optimization based EMS	5:00am – 8:00pm	0	1/2	2:00pm – 6:00pm	2840.02	38.84	0	2840.02
		10	1		2457.88	34.40	1.18	3810.43
		20			2602.97	38.86	1.69	4542.23
		30			2585.11	40.11	2.22	5138.21
		10	2		2449.58	32.54	0.84	3419.93
		20			2502.83	35.62	1.04	3701.47
		30			2593.74	38.18	1.51	4324.38
Hybrid EMS		0	1/2		2303.74	30.11	0	2303.74
		10	1		2355.55	32.31	0	2355.55
		20			2358.37	32.00	0	2358.37
		30			2375.28	33.12	0	2375.28
		10	2		2349.81	31.11	0	2349.81
		20			2356.84	32.94	0	2356.84
		30			2357.51	32.04	0	2357.51